

## Wave-ice interaction and the Marginal Ice Zone

Prof. Peter Wadhams

Department of Applied Mathematics and Theoretical Physics  
University of Cambridge  
Wilberforce Road  
Cambridge CB3 0WA, UK

phone: +44 1223 760372 fax: +44 1223 765900 email: [p.wadhams@damtp.cam.ac.uk](mailto:p.wadhams@damtp.cam.ac.uk)

Dr. Martin Doble

Polar Scientific Ltd., Dallens, Appin,  
Argyll PA38 4BN, Scotland

phone: +44 1631 730013 email: [martin@polarscientific.com](mailto:martin@polarscientific.com)

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### LONG-TERM GOALS

The long-term goal is to gain a complete understanding of the physical processes involved in the interaction between ocean waves and a sea ice cover, in terms, of scattering, attenuation, and mechanical effect of the waves on the ice.

### OBJECTIVES

The main thrust of our work in this project has been to design, build and deploy a large number of wave-measuring buoys, subsequently using them to acquire an unprecedented volume of in-ice directional wave data. These data will be used by the modelling community to parameterise and understand the influence of incoming ocean waves on sea ice, and the effect of the ice on the waves (attenuation, spreading).

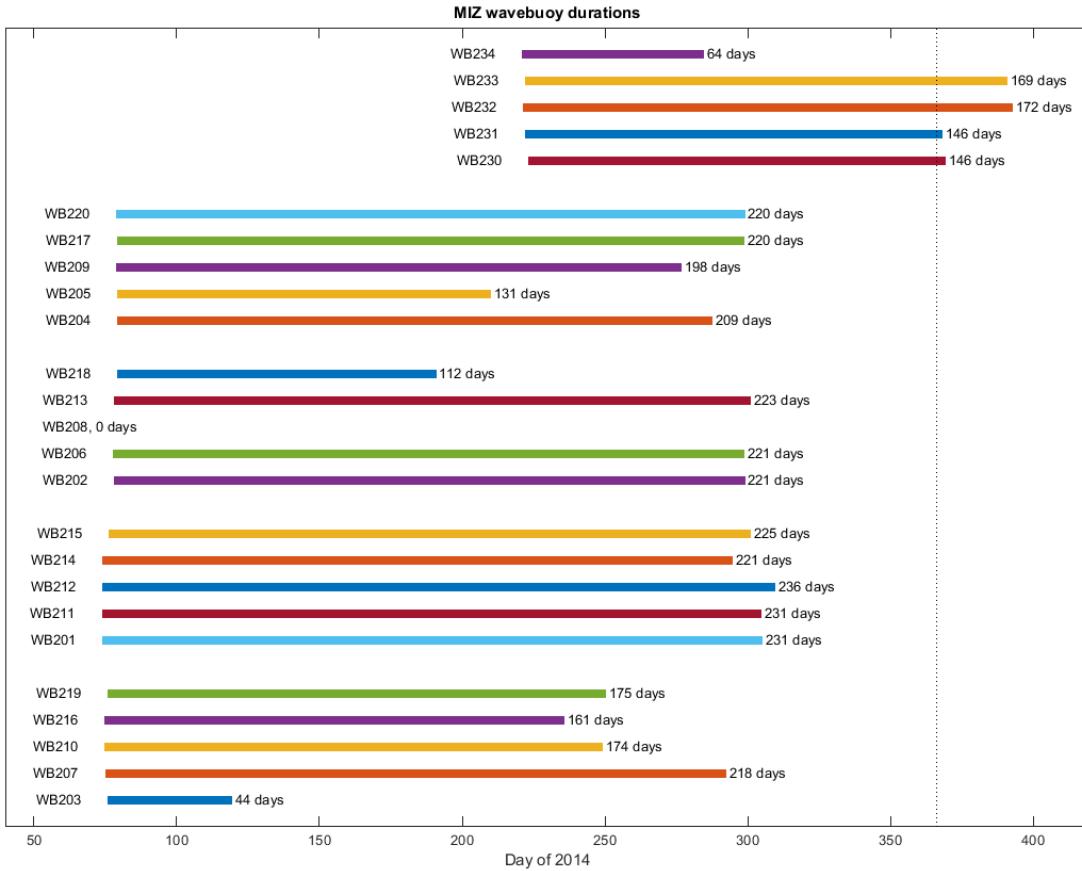
### APPROACH

The observational effort was focussed on the deployment of 25 autonomous, satellite-reporting wavebuoys, deployed in April 2014 from lightweight air-supported ice camps and in August 2014 from the South Korean icebreaker *Araon*. Buoys were designed and built in collaboration with the British Antarctic Survey (UK), key personnel being Dr. Martin Doble and Dr. Jeremy Wilkinson (BAS), and were funded through an agreed pooling of Prof. Wadhams' and Dr Wilkinson's budgets.

### WORK COMPLETED

The period saw the cessation of the wave buoys' transmissions. Clusters 1-4 ceased transmission as the solar panels stopped providing energy during the dark Arctic winter and the on-board alkaline packs finally ran out of power. This occurred around the end of October/beginning of November 2014.

Remote sensing images and the buoys' own webcams suggested that the buoys were either in open water or very low ice concentrations at the time. Any ice present appeared to be fragments of deformed ice (ridges), as most of the level ice had melted.



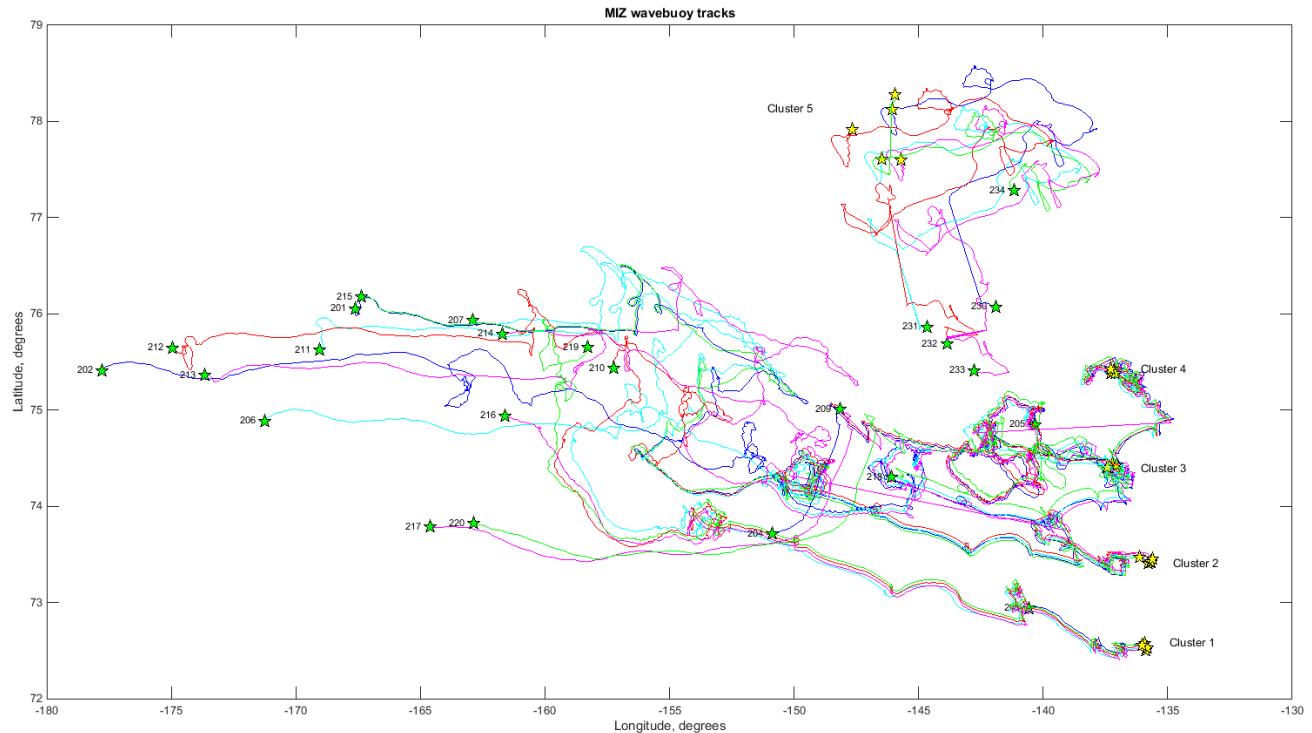
**Figure 1: Final transmission durations of the 25 wavebuoys deployed under the MIZ DRI, organised by Cluster (Cluster 1 at the bottom, Cluster 5 at the top).**

We had expected several buoys to start transmissions again once the sun returned in March and began to charge the batteries, but this did not occur. It may be that the challenging environment in which the buoys found themselves - thin new ice surrounded by the old ridge fragments - crushed the buoys in the significant convergent dynamics of the late autumn/early winter storms that the region experienced. Cluster 5 buoys largely survived through summer and autumn into 2015, with two buoys lasting until the end of January 2015.

## RESULTS

The summer of 2014 did not see any energetic wave events penetrate deep into the pack ice to be measured by the buoys, in contrast to our expectations. Energetic wave events were only experienced once the buoys had approached the edge of the melting pack ice, from late August, when the vast floes had already fragmented due to dynamics and thermodynamics. Once this occurred, then the array measured several days of wave propagation across several buoys, as shown in the figure below. This shows the heave spectra from six buoys aligned in the wave propagation direction, with a SWIFT buoy

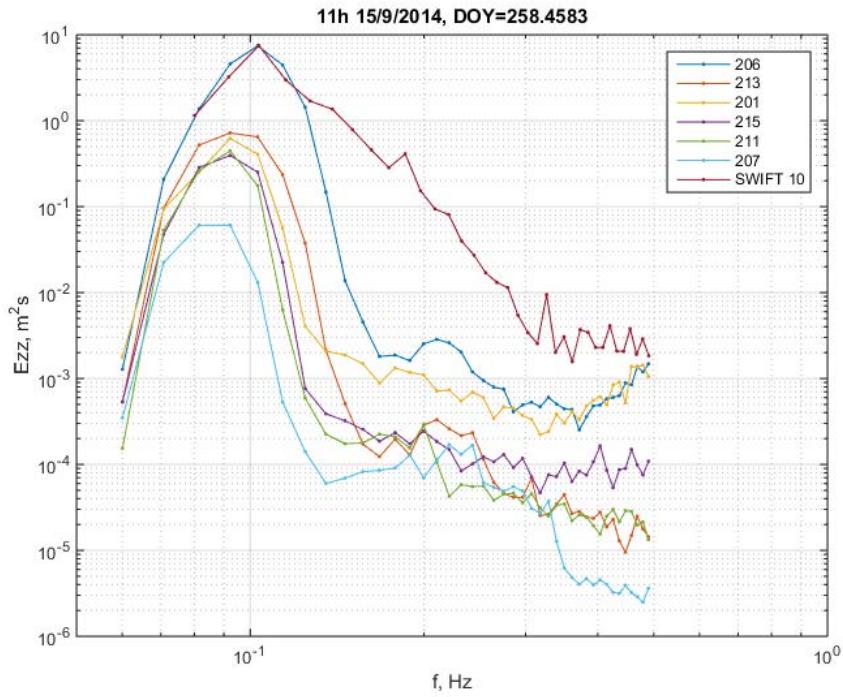
of APL/UW (Thomson) providing the no-ice, open-water input forcing. Wave events are highly episodic, but are distributed over several buoys, as planned.



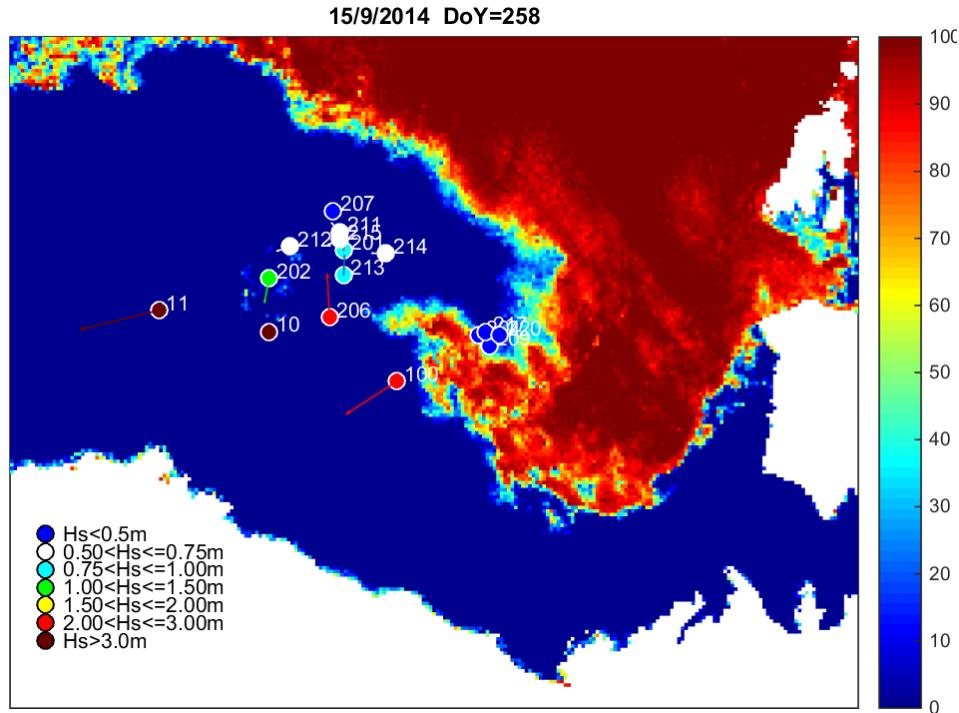
**Figure 2: Final tracks of the 25 deployed wavebuoys. Initial deployment durations are marked with yellow stars, along with the cluster designation. Location at the last transmitted GPS position are marked with green starts, together with the buoy's identification number .**

Analysis of the results is ongoing and complex, requiring extensive use of the remarkable remote sensing image library acquired by the project, as well as the open water data from the Thomson (APL) SWIFT buoys and ice thickness data from the SAMS and WHOI ice mass balance buoys. As such, it is a highly collaborative effort.

The initial analysis is proceeding with a planned three-part contribution to the DRI's *Elementa* Special Issue. These linked components of a paper entitled "*Wave-ice interaction in the marginal ice zone of the Beaufort Sea, measured with a persistent array of autonomous wavebuoys*" - are each led by one of the three 'wave PIs' (Wadhams, Doble, Wilkinson), but with all three partners contributing to each. The papers will concentrate on: 1) the wave ice environment; 2) wave attenuation within the ice cover; 3) the directional evolution of the spectra and floe breaking effects. In the first instance, an abstract was submitted to the Ocean Sciences 2016 meeting in New Orleans, titled "*Waves in the Beaufort Sea MIZ observed with a dense and persistent array of wavebuoys from spring to autumn 2014*".



**Figure 3:** Heave spectra from six wavebuoys aligned in the wave propagation direction, showing the progressive wave attenuation by ice from the open water, input energy (SWIFT 10).



**Figure 4:** Spatial arrangement of the buoys for the spectra shown in Figure 3. Symbol colour indicates the waveheight experienced by the buoy, with SWIFTS in open water seeing more than 3m and the wavebuoys in low concentration ice cover seeing progressively less energy as the waves cross the old ridge fragments

## **IMPACT/APPLICATIONS**

The diverse and comprehensive suite of autonomous measurements performed represents a very significant addition to the total data record of MIZ processes. The simultaneity of data retrieval from many buoys marks a significant advance on previous MIZ programs involving waves, where sequential measurements were made from single buoys that were moved from place to place. These new data, obtained within the comprehensive set of ocean, ice and atmosphere sensors and remote sensing facilities described in the Science and Experiment Plan (Lee et al., 2012), will have significant impact on our understanding of Arctic MIZ processes as the consortium enters the synthesis and analysis phase for the remaining year of the project.

## **Travel**

Wadhams and Doble attended the MIZ DRI meeting in Seattle on 18-19 June 2015 and the ONR mid-term review in Washington D.C. on 26-31 October 2014.

## **RELATED PROJECTS**

“Proving and improving wave models in the Arctic Ocean and its MIZ”, Sea State DRI, Award Number N0014-13-1-0290

## **REFERENCE**

Lee, C.M. + XX (2012). Marginal Ice Zone (MIZ) Program: Science and Experiment Plan. Technical Report APL-UW 1201, October 2012, Applied Physics Lab., University of Washington.